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Abstract: The Automatic Alignment system in the National Ignition Facility is responsible for aligning 192 laser beams using camera sensor images. This paper reviews some of the image processing algorithms that generate the crucial alignment positions.

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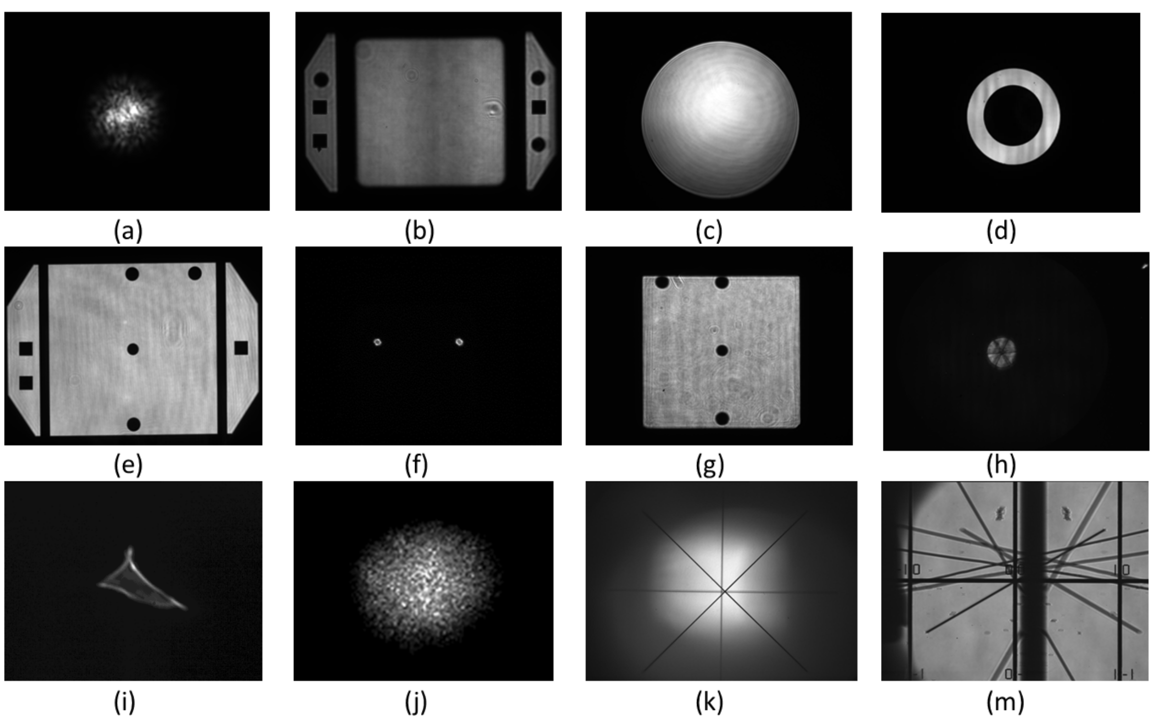
1. Introduction

The Automatic Alignment (AA) system in the National Ignition Facility (NIF) aligns 192 laser beams by adjusting 80 to 160 mirror positions with features in camera sensor images. The alignment of NIF 192 beam high power laser systems [1] relies on precise and accurate position data from CCD images to perform close loop alignment [2-3]. The Automatic Alignment system estimates the beam positions using image feature processing algorithms. If unexpected changes occur in the electro-mechanical system in any of the numerous optical paths, corresponding images will be distorted. Mirrors are then adjusted to minimize the difference between the analyzed positions and a known, accurate reference measurement of physical beam center [4]. In addition, all of the AA algorithms include an off-normal detector [5] which shuts down the automated system when necessary, allowing an operator to intervene and mitigate the condition.

2. Alignment principle and image types

Basic beam alignment is based on sequence of centering and pointing processes [6]. In each of these processes the beam position and reference beam position must be determined. Each control loop must align the beam position to the reference beam position. The position of both the beam and the reference beam are found using a variety of fiducials, some of which are shown in Figure 1.



Fig, 1 Sample of different images, fiducials can include lines, circles, centroids, spots, squares, etc.

Many AA loops involve centroiding beam shapes in images that originated as a Gaussian beam and have been distorted along the beam path, typically by optical defects or poor wavefront correction, as in Fig 1(a)(j). Other alignment loops involve position estimates of spatial shapes such as circles, squares, triangles, or diffused shapes or lines. In the next section, we will describe the many of the image processing algorithms and its framework.

3. Image processing algorithms

AA algorithms consist of three distinct modules: (1) an off-normal detector, (2) an image analysis algorithm, and (3) an uncertainty detector. The off-normal detector detects and rules out images such as all-black or all-white images that contain no information. The detector also tests images for expected beam size, signal level, energy level, etc. The uncertainty detector measures the spread of the data using the position calculations [7].

As noted earlier, many AA loops involve a Gaussian beam in the image. Its position is typically evaluated using a weighted centroid algorithm [8]. Most of the other alignment loops involving a specific spatial shapes such as circles, squares or lines require more complex algorithms. For some geometric shapes, matched filtering [9-10] is used to provide adaptable and accurate position estimates.

In the case of pinhole images, Fig. 1(c), a rough estimation of the pinhole size is performed first. An adaptive search is then executed to locate the best match circle center [11]. For the smaller square and circle fiducials, Fig. 1(b)(e)(g), the search is conducted between the pre-estimated size range [11]. For larger size images, sub-imaging [12] is done to reduce to the time for producing the match position estimates. For two spot images, such as in Figure 1(f), composite templates [13] are designed using archived images [14]. A predesigned template matching strategy is used in the triangular shape beam, Fig. 1(i)) [15], and the corner cube, Fig. 1(h)) image [16].

In order to increase reliability and robustness of laser alignment in the presence of noise and variable illuminations, redundant algorithms are often stacked such that when one fails, a less involved algorithm can provide position data [11]. For line and intersection detection, Fig. 1(k)(m), local line segments are detected using difference methods which are then connected using a modified Hough transform to produce a final line fit [17].

4. References

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